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Shoe Wear Indicator

TECHNICAL FIELD

The present invention relates to shoes capable of indicating the approximate remaining useful life of the shoes, and more specifically, to shoes capable of recording data relating to impacts experienced by the shoe, using the collected data to estimate the remaining useful life of the shoe, and displaying the results in a manner visible or audible to the user.

BACKGROUND ART

Shoes are generally considered to be an essential item of apparel by most people for reducing the likelihood of injury, particularly when engaging in activities such as sports and running.

A typical generic athletic or active wear shoe includes a relatively soft and flexible upper portion for surrounding at least part of the wearers foot, including a pair of side flaps which define a foot recess, a shoe tongue extending between the side flaps, and a means for securing the shoe side flaps to each other. Such shoes typically further include a sole to provide protection from and cushion against uncomfortable contact with a supporting surface such as the ground. The sole will typically further comprise a series of layers of differing materials with differing characteristics, such as

a tough outsole component, a cushioned midsole component, and a soft insole component. The sole is typically affixed on its upper surface to the lower margin of the upper portion of the shoe by the use of an adhesive.

The midsole of conventional shoe construction functions as a shock absorber to cushion impacts experienced by the user's foot, and will deform in response to force exerted against it. The compression and decompression characteristics of the midsole layer are important both for protecting the user, and for the longevity of the shoe. The shock absorbing capability of the midsole of conventional shoes tends to progressively deteriorate with use. Consumers of shoes, particularly athletic shoes and running shoes, are concerned with knowing when a shoe needs to be replaced. Wear on the outsole can be easily checked with an occasional visual inspection of the sole of the shoe. However, it is often difficult to tell when a shoe has lost its ability to provide sufficient cushioning or shock-absorbing effects.

Failure to replace shoes when the shock-absorbing abilities of the shoe have deteriorated may result in severe or disabling injuries. On the other hand, athletic shoes are generally perceived to be very expensive and premature retirement of shoes by as little as 5% to 10% of the anticipated life of the shoes may result in the perception of a significant unwarranted expense or cost to the consumer.

Prior efforts have been made to develop a shoe that would indicate when the shock-absorbing ability of the shoe has deteriorated, and that the shoe must be

experienced by the sensor. In other embodiments the shoe comprises at least two sensors. In such embodiments, it is preferable that at least one sensor be positioned in the sole of the shoe proximate the heel, and another in the sole of the shoe proximate the ball of the foot.

In some preferred embodiments the shoe further comprises a button or switch to activate the display. In a further preferred embodiment, the shoe further includes a resistor network between the sensor and the operational circuitry. In some embodiments, the operational circuitry may comprise a microprocessor. The resistor network preferably converts the signal to a useable voltage and converts the signal to a form able to be used by digital electronics, and the resistor network preferably sends signals to the operational circuitry which allow the detection and differentiation of signals of varying signal strength received from the sensors.

The sensors may comprise a piezoelectric element, and may further comprise a rigid element positioned in contact with, or near the piezoelectric element to enhance the deformation of the piezoelectric element. The rigid element preferably extends transversely across the upper surface of the piezoelectric element, although in alternate embodiments the rigid element may be positioned effectively in other locations.

The display may be visual or audible or both, and in alphanumeric or graphical format. The display used may include light emitting diodes, electroluminescent

panels, liquid crystal displays, flexible liquid crystal displays, or any other kinds of displays adaptable for use in the invention.

The invention further comprises a method for estimating the approximate useful remaining life of the shock absorbing capability of the shoe, wherein the shoe comprises at least one sensor, operational circuitry in communication with the sensor, wherein the operational circuitry is capable of manipulating data received from the sensor to estimate a remaining life of the shock absorbing capabilities of the shoe, a power source electrically coupled to the operational circuitry, and a display in communication with the operational circuitry capable of displaying information related to the remaining useful life of the shock absorbing capabilities of the shoe; the method comprising the following steps: (a) providing a pre-determined numerical value; (b) receiving a signal; (c) applying an algorithm to derive a value; (d) adding the numerical value of step (c) to a sum of such values to create a new value; (e) comparing the new value of step (d) to the pre-determined value of step (a); (f) estimating the remaining life of the shock absorbing ability of the shoe based on the results of the comparison in step (e).

The method of the invention may also comprise the step of (g) displaying the remaining life of the shock absorbing capability of the shoe based on the results of the comparison in step (e). In another embodiment, the signal from the sensor may be conditioned before step (b). Also, the method of the invention may be performed separately for separate sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cutaway side view of an athletic shoe according to the invention.

FIG. 2 shows a block diagram of an embodiment of circuitry of the invention.

FIG. 3a shows a cutaway side view of the sole of a typical athletic shoe with an embodiment of the impact sensor in a neutral position.

FIG. 3b shows a cutaway side view of the sole of a typical athletic shoe with an embodiment of the impact sensor while being deflected.

FIG. 4 shows a schematic of an embodiment of the impact detection circuitry of the invention.

FIG. 5 shows a perspective view of the upper of the heel of an embodiment of the invention.

FIG. 6 shows a perspective view of an alternate embodiment of the upper of the heel of an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a shoe including one or more impact sensors to provide data relating to impacts experienced by the shoe. The shoe further includes apparatus for collecting; storing, and analyzing the data in order to estimate the remaining useful life of the shoe, and that displays or conveys the results in a form comprehendible by the user of the shoe.

The invention will be described by reference to the Figures 1 through 7, wherein like numbers refer to similar features. Although the Figures and the following detailed description show and discuss the invention in use on a typical athletic shoe, it is understood that the invention could be incorporated into any kind of footwear, including but not limited to dress shoes, boots, sandals, slippers, overshoes, and the like. Furthermore, the particular configuration of the shoe, and the method of making the shoe, are not critical to the invention, and any known and acceptable methods or means for manufacturing the shoe may be used.

FIG. 1 shows a cutaway side view of a conventional generic athletic shoe 100 constructed in accordance with a preferred embodiment of the invention. The conventional athletic shoe 100 includes a relatively soft and flexible upper portion 102 for surrounding at least part of the wearers foot, including a pair of side flaps which define a foot recess, a tongue 106 extending between the side flaps, and a means for

securing the shoe side flaps to each other. Typically, laces are threaded through a plurality of lace eyelets disposed along parallel opposing sides of the flaps to secure the shoe 100, however, other fastening means such as known hook and loop fastener straps or elastic materials may be used. The shoe 100 further includes a sole 110 to provide protection from and cushion against uncomfortable contact with a supporting surface such as the ground. Typical materials used in the upper portion 102 of the shoe 100 include leather and man made sheet materials such as polyvinyl or polyurethane sheets, or a combination thereof. The particular materials used in the upper portion 102 of the shoe 100 are not critical to the invention. These materials may be die-cut or laser-cut and stitched over a foot shaped last to form the finished upper portion 102 . The sole 110 is typically molded or formed from one or more elastomeric materials such as foamed or solid polyurethane or ethylene vinyl acetate, and are configured to include common structural features such as a top or footbed surface, a peripheral outer or side wall surface, and a bottom or ground contacting surface. The particular configuration of the sole 110 of the shoe 100 is not critical to the invention. The sole of a typical simple athletic shoe will typically comprise a series of layers of differing materials with differing characteristics. The shoe 100 of FIG. 1 includes a tough outsole 112, a cushioned midsole 114, and an insole 116. The sole 110 is typically affixed on its top surface to the lower margin of the upper portion 102 of the shoe 100 by the use of an adhesive.

A key element of the invention is the ability of the shoe 100 to monitor impacts experienced by the shoe 100, which allows an estimation of the remaining life of the shock absorbing capability of the shoe 100 based on analysis of the collected

impact data. Thus, the invention deviates from a conventional shoe design in having certain apparatus associated with the shoe 100 for performing the desired function. Referring to FIG. 1, the major components include at least one force or impact sensor 120, operational circuitry 122 to manipulate the data received from the impact sensors 120, display apparatus 124 for displaying a signal from the operational circuitry 122 either in audible or visual form, and a power source 126 to provide the necessary electric power. The invention also preferably includes a switch or button 128 for activating the display 124. FIG. 2 shows a block diagram of an embodiment of circuitry of the invention of FIG. 1.

Referring to FIG. 1, at least one impact sensor 120 is preferably located under either the ball of the foot or the heel, however, it is preferred that two or more impact sensors 120 be used, so that at least one impact sensor 120 is located under both the heel and the ball of the foot. The impact sensor 120 is preferably molded into the midsole 114 of the shoe 100, although in alternate embodiments the impact sensor 120 could be located elsewhere. For example, the impact sensors 120 may be located in the insole 116, or under the insole 116 but above the midsole 114, or adjacent to the outsole 112, or in any other desired location. In some alternate embodiments, it may be desirable to use an accelerometer as the impact sensor 120 located in the upper portion 102 of the shoe.

Impact sensors, pressure sensors, accelerometers and the like are generally well known, and many kinds of such devices may be useable in the present invention. It is preferable that the sensor 120 be inexpensive, easily customizable for different

shoe designs and configurations, and compact in size for easy incorporation into various shoe designs. Because the impact sensors 120 are preferably embedded in the sole 110 of the shoe 100 and may not be easily replaceable, it is preferable that the impact sensors 120 be rugged and resistant to mechanical fatigue. In preferred embodiments of the invention the impact sensors 120 can also sense the magnitude of the force of the impact experienced by the shoe 100, and provide a signal that conveys data regarding the force of the impact.

Piezoelectric force sensors have been found to typically include the desired characteristics discussed above, and LDT-0 piezo ceramic material made by Measurements Specialties Incorporated has been used successfully in prototypes. If a single sensor 120 is inadequate to provide the desired signal strength, additional sensors 120 may be used to increase the signal strength. Additional sensors 120 may also be used to improve the monitoring of the shoe wear. FIGS. 3a and 3b, show one preferred embodiment of an impact sensor 120 wherein the sensor 120 comprises a laminate piezoelectric sheet element 132 with a rigid element 134 positioned above the piezoelectric sheet element 132. Referring to FIG. 3a an impact sensor 120 is shown in a neutral position with the rigid element 134 laminated onto the piezoelectric sheet element 132. In alternate embodiments, other configurations may be used, or the rigid element 134 may simply comprise a local higher density foam. In the embodiment shown, the sensor 120 is positioned between the midsole 114 and the insole 116 of the sole 110 of the shoe 100. When a wearer takes a step, for example, the impact of the step will cause the foot to compress the compressible midsole 114 of the sole 110 of the shoe 100 as seen in FIG. 3b. This compression will cause a

deflection of the piezoelectric sheet element 132 of the impact sensor 120. The rigid element 134 increases the localized deflection of the piezoelectric sheet element 132. The deflection of the piezoelectric sheet element 132 generates a current proportional to the degree of deflection, and thus proportional to the force of the impact experienced by the sensor 120.

Referring to FIG. 2, The impact sensors 120 are electrically coupled to the operational circuitry 122, which preferably includes some kind of microprocessor 140. The current output from an impact sensor 120 configured as set forth above is quite low, possibly as low as one micro amp. The small varying levels of current output from the sensor 120 must be detected by the microprocessor 140. Conventional design techniques suggest the use of an amplifier to convert the low current to useable voltage. However, a suitable amplifier would be prohibitively expensive. The preferred solution is to use a resistor divider network 142 in conjunction with the inherent characteristics of the microprocessor input pins 144 to detect varying levels of sensor 120 current output. The voltage of the system is equal to the current from the sensors 120 multiplied by the resistance of the resistor network 142, and the use of high impedance resistors in the resistor network 142 allows the generation of a useable voltage level from the low current provided by sensors 120, which also has the simultaneous effect of performing an analog to digital signal conversion.

FIG. 4 shows a schematic of a preferred embodiment of the circuitry of the resistor network 142 including a series of high impedance resistors 146 configured such that a number of microprocessor input pins 144 are connected between the

resistors 146. Only a single impact sensor 120 with a three threshold level resistor network 142 is shown in FIG. 4. However, in alternate embodiments, the as little as one threshold level could be used, and any number of sensors 120 may be used, and the sensors 120 may aggregate the signals to a single resistor network 142, or the sensors 120 may have separate resistor networks 142, or a combination thereof, depending on what is being accomplished with a given sensor 120. Furthermore, the threshold levels may be the same or different for different sensors 120, and the number of thresholds may be varied between sensors 120 as desired. For example, in some embodiments, it may be desirable to use only two threshold levels for the sensor 120 under the ball of the foot in the shoe 100, but to use three threshold levels for the sensor under the heel of the foot in the shoe 100.

The individual resistor 146 impedance values are chosen such that the logical high input condition of selected input pins 144 are met when a certain selected impact threshold is reached. Thus, the impedance values of the resistors 146 are preferably not identical. The threshold values selected are preferably determined by reference to test data obtained from actual tests performed on actual shoes 100, or on the materials used in the shoes 100.

In the case of a three threshold system as shown in FIG. 5, a low threshold signal, for example a signal generated by a walking impact, would be sensed when the sensor 120 output current is sufficiently high to generate a voltage that meets or exceeds the logic high voltage of only one input pin 144.

A medium threshold signal, such as a signal generated by a running impact for example, would be sensed when the sensor 120 output current is sufficiently high to generate a voltage that meets or exceeds the logic high voltage of only two input pins 144.

A high threshold signal, for example a signal generated by a jumping or sprinting impact, would be sensed when the sensor 120 output current resulted in a voltage that is sufficiently high to generate a voltage that meets or exceeds the logic high voltage for all three input pins 144.

As previously stated, the operational circuitry 122 preferably comprises an integrated circuit device such as a microprocessor 140 formed using conventional or known integrated circuit manufacturing techniques. The operational circuitry 122 is preferably positioned at a location in the sole 110 of the shoe 100 that experiences as little flexure or stress as possible. However, in alternate embodiments the operational circuitry 122 could be positioned virtually anywhere on the shoe 100. As has been explained, it is the primary object of the invention to calculate and display an estimated remaining useful life of the shock absorbing capabilities of the shoe 100. However, in alternate embodiments, the sensors 120 and the operational circuitry 122 may also be used to sense, analyze, and display other kinds of data of interest to the user, and to perform other data analysis functions relating to the use the shoe 100.

Based on the environment in which the operational circuitry 122 must function, it is preferable that the operational circuitry 122 has low power requirements

to reduce the demand on the power source 126. It is currently preferred that the operational circuitry 122 operate on a voltage range between 1 and 9 volts, and more preferably approximately 3 volts. It is also preferable that the operational circuitry 122 be inexpensive, compact in size, and easily customizable for integration into various shoe 100 designs. Finally, it is also preferable that the operational circuitry 122 be rugged and resistant to mechanical fatigue. The operational circuitry 122 can be assembled from off the shelf or customized components. In alternate embodiments, it may be necessary or desirable to include a voltage limiting device to protect the operational circuitry from high sensor output levels.

In prototypes, a Microchip PIC 16C505 microprocessor, mounted on a small board including the resistor network 142, has been used successfully as the microprocessor 140 in the operational Circuitry. In alternate embodiments, much of the operational circuitry 122 may be placed in a single ASIC (Application Specific Integrated Circuit) or other custom circuitry with ease. In this embodiment, it is preferred that the ASIC or other custom circuitry have a low cost surface mount package to reduce manufacturing costs, and the resistor network 142 is preferably formed in the ASIC or other custom circuitry. The circuit board may also include a fixture to hold the power source 126. However, in alternate embodiments the power source 126 may be a separate component. The LEDs are wired to the circuit board and are in electrical communication with the power source 126 and the operational circuitry 122 which controls the lighting of the LEDs 152 in response to a wear status request, i.e. activation of the display by depressing button 128. Many modifications to the circuit may be easily made by those skilled in the art.

The power source 126 is preferably mounted on the board of the operational circuitry 122, and is in electrical communication with the operational circuitry 122. A three volt lithium coin cell was used successfully in prototypes. However, many known battery types may be useable or preferred. The preferred battery will be small, inexpensive, and will last for the life of the shoe 100. In alternate embodiments other power sources 126 may be used, including solar panels or fuel cells. In still other embodiments, the power source 126 may be replaceable or rechargeable. In further embodiments, the invention may be powered by the current generated by the sensors, or by other piezoelectric elements. In embodiments using a rechargeable battery, the battery may be charged by the sensors or other piezoelectric elements associated with the shoe, or the battery may be recharged inductively or by a solar panel or other recharge source.

The invention also comprises a display apparatus 124 for displaying a signal from the operational circuitry 122 either in a form that may be perceived by the user, including audible, visual, or tactile form. The wires to the display 124 may be molded into the shoe 100 and may be routed by any acceptable path through the sole 110 of the shoe 100. The display 124 may be located at any convenient location on the shoe 100 or on the upper 102 of the shoe 100, but is preferably located at the heel 108 of the upper 102 of the shoe 100 as seen in FIGS 6 and 7. The location of display 124 selected will depend both on functional and ornamental factors in the design of the shoe 100.

The preferred display 124 is inexpensive, rugged, waterproof, dust proof, impact resistant, compact in size, easily customizable for different shoe designs, and uses little power. Although it is possible to design the shoe 100 such that the display 124 merely displays when the shoe 100 should be replaced, it is anticipated that consumers would prefer to have some warning of the expiration of the shoe 100. Accordingly, it is preferable that the display 124 shows the estimated remaining life of the shoe 100 on a relative scale. For visual displays 124, it is preferable that the display 124 is visible in lighting conditions including low light, ambient indoor lighting, and direct sunlight. Audible displays should be readily audible in various environments, yet not so loud as to embarrass or irritate the user.

Prototypes have been constructed using five LEDs 152 embedded in resin, and given a matte finish to increase the effective viewing angle of the LEDs 152, as seen in FIG. 5. The LEDs 152 may be mounted directly on the shoe 100, or may be mounted under a translucent diffusion panel or cover, such as a molded clear plastic to which a frosted surface has been applied. Such diffusion panels or other suitable apparatus may be used to increase the angles from which the LED 152 light is visible.

Many other modifications of the display 124 are possible within the scope of the invention. For example, the number and colors of the LED's may be varied, or, with appropriate substitution of circuitry, other displays 124 may be used, including but not limited to, as electroluminescent displays, liquid crystal displays, flexible liquid crystal displays, or heat activated displays, may be used for display 124. If such panels are used for display 124, the display 124 may provide alpha numeric

information as seen in FIG 6. The use of panels also allows the use of graphics, images, or pictograms rather than alpha numeric symbols on the display 124. If an audible display 124 is desired, a piezo ceramic element may be used to generate the audible signal.

In order to reduce power consumption, it is preferable that the status of the shoe 100 be displayed only upon user request. Thus, it is preferable that a switch or button 128 be incorporated in the shoe 100 for activating the display 124. A large number of such buttons or switches are known. The preferred button 128 will be small, inexpensive, easily customizable for different shoe designs, waterproof, dust proof, impact resistant, and will provide tactile feedback when activated. In prototypes, a snap dome switch mounted to a flex circuit has been found acceptable for use.

In use, the user wears the shoe 100 like any other shoe 100. No on/off switch is necessary, as the electronics are preferably activated by the receipt of signals from the impact sensors 120. The impact sensors 120 respond to the various impacts experienced by the shoe 100 and send an electrical signal with a signal magnitude that varies depending on the force of the impact strength to the resistor network 142. The resistor network 142 allows the differentiation of the signal by signal strength and converts the analog signal received from the sensors 120 to a signal intended to be detected by digital circuitry, as previously described, and sends the signal to the microprocessor 140. The microprocessor 140 applies pre-programmed algorithms to generate a numerical value. The algorithms applied are preferably based on data

derived from tests on shoes similar to the shoe 100, or on tests on the materials used in the sole 110 of the shoe 100. This value is added to a sum of such values. The accumulated sum of values represents an estimate of the amount of, or accumulation of, wear on the shoe 100. When the display 124 button is depressed, the current sum of values is compared against a pre-determined threshold value. If the threshold has been exceeded, the display 124 will indicate visually or audibly that the shoe 100 must be replaced. In preferred embodiments if the sum is less than the threshold value, the display 124 will indicate an approximate percentage of the life of the shoe 100 remaining.

In alternate embodiments the microprocessor 140 may separately sum the wear in different parts of the sole 110 of the shoe 100. For example, it may be desirable to separately track the accumulation of wear on the heel portion of the sole 110 of the shoe 100 and on the portion of the sole 110 of the shoe 100 under the ball of the foot, so that if the shock absorbing ability of one portion of the sole 110 expires before the other, the user may be informed that the shoe should be replaced.

(a) providing a pre-determined numerical value; (b) receiving a signal from an impact sensor; (c) applying an algorithm to derive a value; (d) adding the numerical value of step (c) to a sum of such values to create a new value; (e) comparing the new value of step (d) to the pre-determined value of step (a); (f) estimating the remaining life of the shock absorbing ability of the shoe based on the results of the comparison in step (e).

The method of the invention may also comprise the step of (g) displaying the remaining life of the shock absorbing capability of the shoe based on the results of the comparison in step (f). In another embodiment, the signal from the sensor may be conditioned before step (b), preferably by using a resister divider network. Also, the method of the invention may be performed separately for separate sensors.

To those skilled in the art, many changes and modifications will be readily apparent from consideration of the foregoing description of a preferred embodiment without departure from the spirit of the present invention; the scope thereof being more particularly pointed out by the following claims. The description herein and the disclosures hereof are by way of illustration only and should not be construed as limiting the scope of the present invention which is more particularly pointed out by the following claims. For example, the invention has been disclosed in the context of an athletic shoe, however, the invention may be incorporated in to many other kinds of shoes or other footwear.